Inside INEEL

An inside look at the Idaho National Engineering and Environmental Laboratory

INEEL
Home of Science and Engineering Solutions

February 2001
Idaho Falls, Idaho

Scientists use natural bacteria to help break down solvents in groundwater

Linking research to operations

Idaho National Engineering and Environmental Laboratory scientists are demonstrating a faster, more effective, less expensive way to clean up groundwater contaminated with hazardous solvents by using microbes.

"We're very excited about it," said Kent Sorenson, principal scientist/engineer on the INEEL's Test Area North groundwater cleanup.

"It's fun to find new solutions to serious contamination problems that are worldwide issues. Any site that has residual solvent contamination is potentially amenable to this approach."

The INEEL has been proving the effectiveness of bioremediation during the past two years with ongoing cleanup of a two-mile-long, half-mile-wide solvent contamination plume in groundwater beneath Test Area North. The innovative techniques that are destroying hazardous trichloroethene (TCE) also have great potential to clean up similar pollution that plagues groundwater in many other places worldwide.

One of the project's innovations is enhanced in situ (in place) bioremediation.

Enhanced In Situ Bioremediation

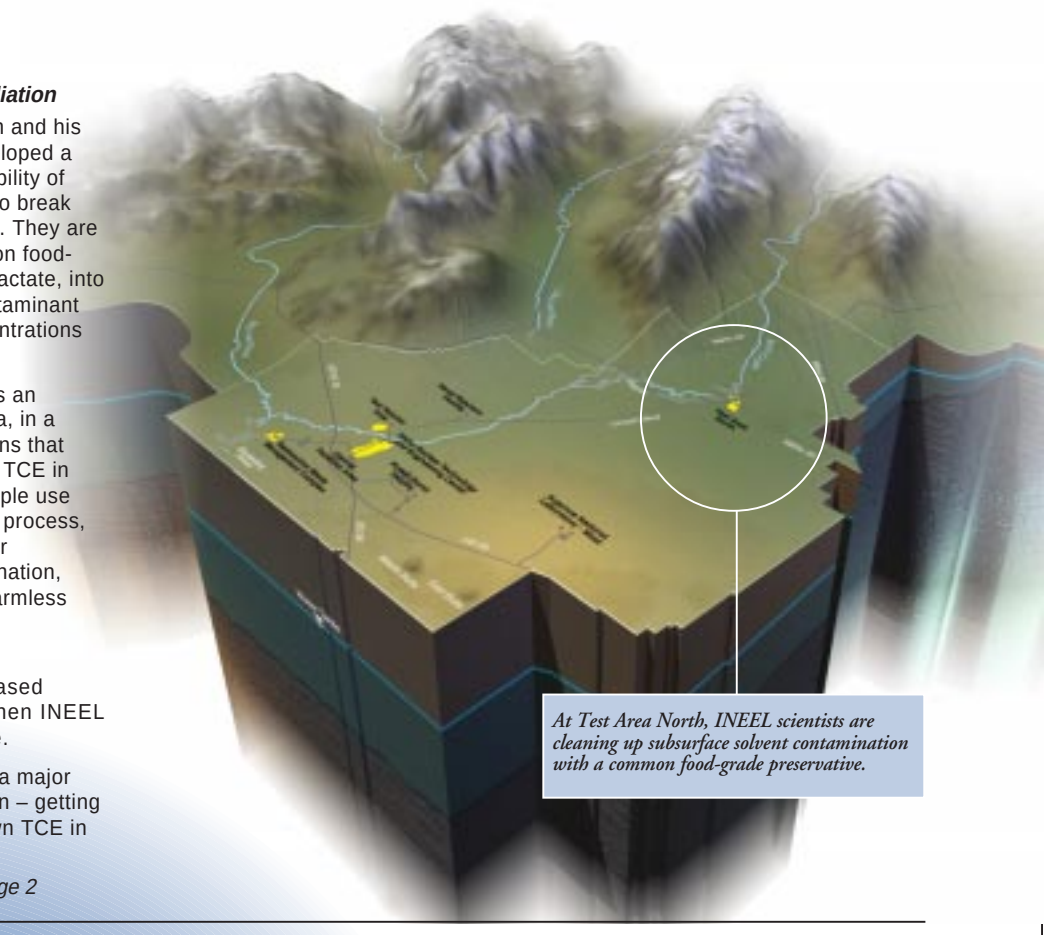
At Test Area North, Sorenson and his INEEL colleagues have developed a way to greatly improve the ability of natural subsurface bacteria to break down the chlorinated solvent. They are doing it by injecting a common food-grade preservative, sodium lactate, into the upstream part of the contaminant plume where pollution concentrations were highest.

The sodium lactate serves as an electron donor to the bacteria, in a series of biochemical reactions that stimulate the bacteria to use TCE in much the same way that people use oxygen when breathing. The process, known as chlororespiration or anaerobic reductive dechlorination, breaks down TCE into the harmless chemical ethene.

It's working. Contaminant concentrations have decreased dramatically since 1998, when INEEL started using the technique.

The INEEL team has solved a major challenge with bioremediation – getting bacteria to rapidly break down TCE in

*See **Groundwater,** page 2*



At Test Area North, INEEL scientists are cleaning up subsurface solvent contamination with a common food-grade preservative.

A construction crew backfills to cover 16-inch distribution pipes that run from INTEC to the new percolation ponds (above). A construction worker completes the heat fusion process used to join pipe sections together (left).

Pond allows researchers to trace subsurface water movement

Next fall, a million gallons of water from the Idaho Nuclear Technology and Engineering Center will travel almost two miles across the desert every day. The destination: a man-made pond where the water will slowly seep into the ground, drawing along with it the vigilant interest of INEEL researchers.

The INEEL plans to divert equipment-cooling water from INTEC to a new location. Moving the infiltration pond helps regulators and INEEL's environmental management team alleviate concerns that the water might be contributing to contaminant migration under the facility. Even though the water is clean, the tremendous volume seeping into soils is keeping the ground partially saturated—possibly forcing existing contaminants in the ground to move laterally. The new pond offers an opportunity to create a vadose-zone research park to study how water moves

*See **Percolation Pond,** page 3*

Putting science to work

Inside INEEL *is published twice a year to tell citizens about the important scientific research, energy development, environmental technology and national security work being performed at the U.S. Department of Energy's Idaho National Engineering and Environmental Laboratory in southeastern Idaho. The lab's*

6,260 employees work in partnership with seven regional universities to help solve some of the world's most challenging problems. We're proud to be associated with the University of Idaho, Boise State University, Idaho State University, Washington State University, the University of Montana, Montana State University and Utah State University. For the first time, we are also inserting this publication in the hometown newspapers of the Montana and Utah universities.

This column by Dr. Bill Shipp, INEEL laboratory director, explains why science and the universities are so important to achieving the site's missions. Dr. Shipp is also Idaho Governor Dirk Kempthorne's science and technology advisor.

By Dr. Bill Shipp

For over half a century, Idaho National Engineering and Environmental Laboratory workers have contributed to America's nuclear and energy missions. Today, the INEEL is applying science and engineering technology to support the nation's environmental cleanup, energy, nuclear technology and national security needs. As the INEEL cleanup proceeds, we always ask ourselves: "Is the work we're doing based on sound science?"

We must answer this question because the nation must have the most proven scientific research behind every cleanup decision we make. Although the country is experiencing a budget surplus, the extra money starts looking less and less significant when the costs of cleaning up Idaho and the rest of the nation are considered. The latest available projections suggest it will take as much as $200 billion to manage national environmental cleanup activities between now and the year 2070. Estimates indicate about $21 billion of that amount will be needed in Idaho.

Applying the best available science to environmental challenges in the beginning can ultimately save taxpayers' dollars. Science does make a difference. As an example, we formerly relied on a dated pump-and-treat technology to remove an industrial solvent from the groundwater beneath one of our facilities. Thanks to the work of INEEL researchers, we found a way to use naturally occurring micro-organisms to do the cleanup work far more effectively. (See story above).

And thanks to solid scientific research, we found a way to stop the migration of organic vapors toward the Snake River Plain aquifer. Rather than dig up and box the contaminated soil, we developed a

*See **Shipp,** page 3*

Published by the Idaho National Engineering and Environmental Laboratory

Powerful Instrument tracks down bacteria, discovers drugs

INEEL scientists recently built one of the most powerful instruments in the world for measuring atomic mass. At the instrument's core is a superconducting magnet so strong it could be used to rip a foreign object such as shrapnel out of a human body.

Researchers use this instrument, known as a Fourier transform mass spectrometer (FTMS), to determine rock composition, to detect bacteria-made proteins and chemicals, and to search for illegal drugs in a single strand of hair.

Other types of mass spectrometers also use magnets, but the FTMS is the only one with the accuracy to repeatedly analyze the same tiny spot on a sample. The FTMS can resolve items as small as half a micron – less than the width of individual bacteria.

"This instrument is unique to the world at the moment," says INEEL chemist Jill Scott. She and engineer Paul Tremblay saved more than half a million dollars by constructing the FTMS themselves instead of ordering a custom-built machine.

Unlike most scales, which use weights and springs, the FTMS measures atomic mass with a magnetic field and metal plates.

Shooting a laser beam at a sample removes the top few layers of atoms from the sample's surface. Energy from the beam makes the atoms quiver with extra energy, until they vibrate themselves right off the surface.

The magnetic field captures these charged particles (atoms and molecules), known as ions. Trapped, the ions orbit within the FTMS. A radio wave pulse further excites the orbiting ions, making them buzz with energy – like hitting a tuning fork. The ions strike metal plates within the FTMS, where sensors read the minute electric charges the ions transfer to the plates. A computer uses a Fourier transform – a mathematical equation – to separate the multitude of charges into individual signals, then converts the signals to mass.

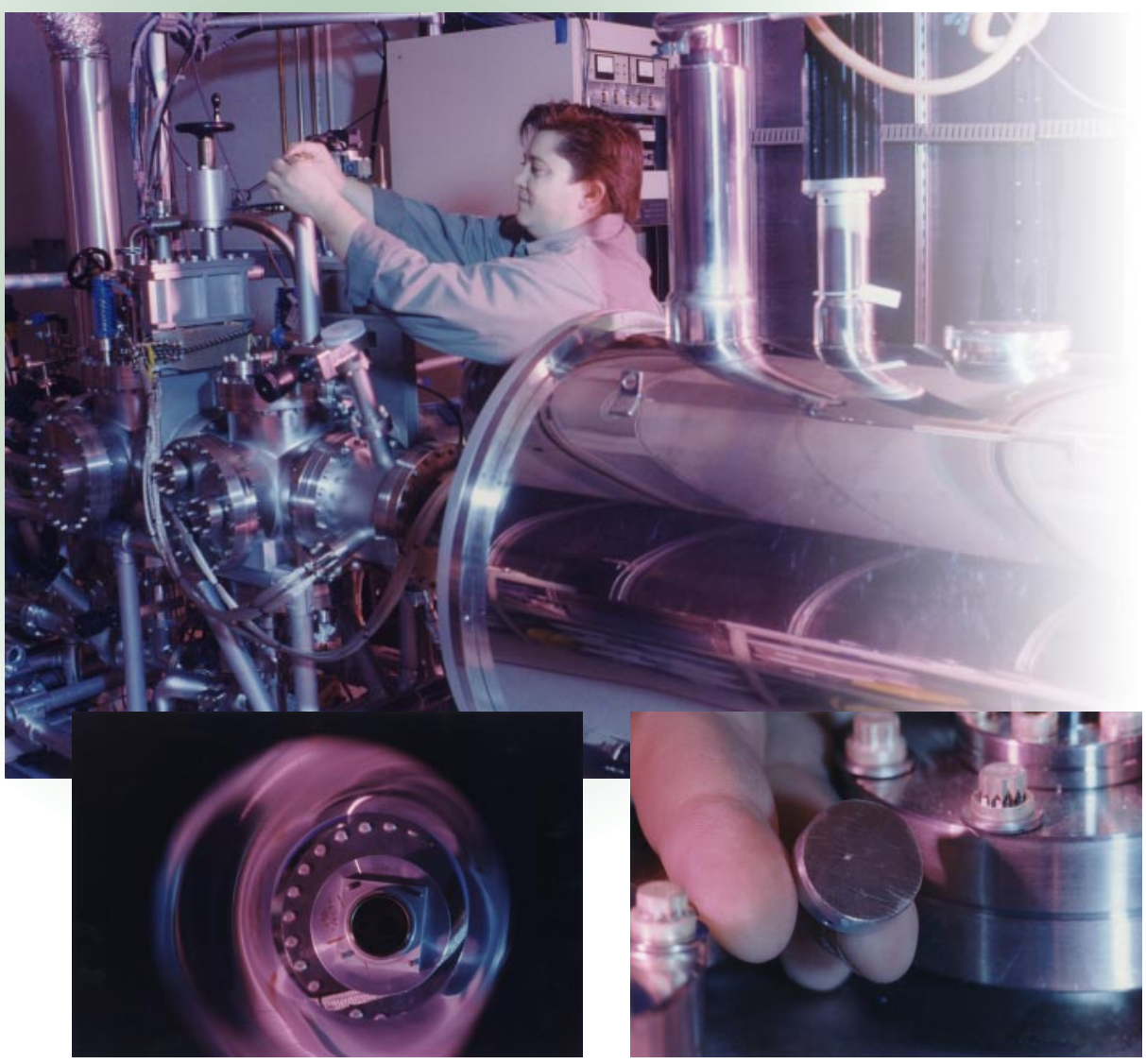
Scott and Tremblay have figured out a way to produce a "pseudo-image" of a sample – a surface map showing chemical composition like a picture shows color. In the future, they also plan to modify the laser beam so it makes bacteria fluoresce – a common technique for detecting bacterial colonies.

For example, they could pick out a single bacterium, analyze how it digests rocks, and then re-analyze the same spot to see what mineral the bacteria lived on. This information will help scientists find bacteria to help with contamination clean up in different rock types.

But the real benefit of the FTMS is that researchers no longer have to travel out-of-town for precise analyses, says Tremblay, reducing costs and turn-around time. "The FTMS is quicker, cheaper, more sensitive, and it's local," he says.

(For more information, call Mary Beckman at 208-526-0061.)

Unlike most scales, which use weights and measures, the FTMS (below) measures atomic molecular mass using a super-conducting magnet and a frequency detector. The magnetic field captures these charged particles, known as ions. Trapped, the ions orbit within the FTMS.



GROUNDWATER

Continued from page 1

groundwater. Adding the nutrient does that so well that INEEL has filed a patent application on the process.

"I think it's very marketable," Sorenson said. "Chlorinated solvents are the most common groundwater contaminants at hazardous waste sites and municipal landfills in the United States."

He noted that area communities looking for ways to clean up TCE-polluted groundwater include Pocatello and Boise in Idaho and Bozeman, Montana.

The project is a prime example of how INEEL is integrating science with its environmental restoration mission at Test Area North, said Lance Peterson, technical manager of innovative treatment technologies for the groundwater cleanup. "We did that. It was a huge challenge."

For about 20 years until the mid-1970s, workers disposed of waste TCE by injecting it down a well at Test Area North — a common practice at industrial sites in those days.

The cleanup remedy that state and federal environmental regulatory agencies agreed on in 1995 involved pumping contaminated groundwater to the surface and treating it to remove the contaminants, then returning clean water to the ground.

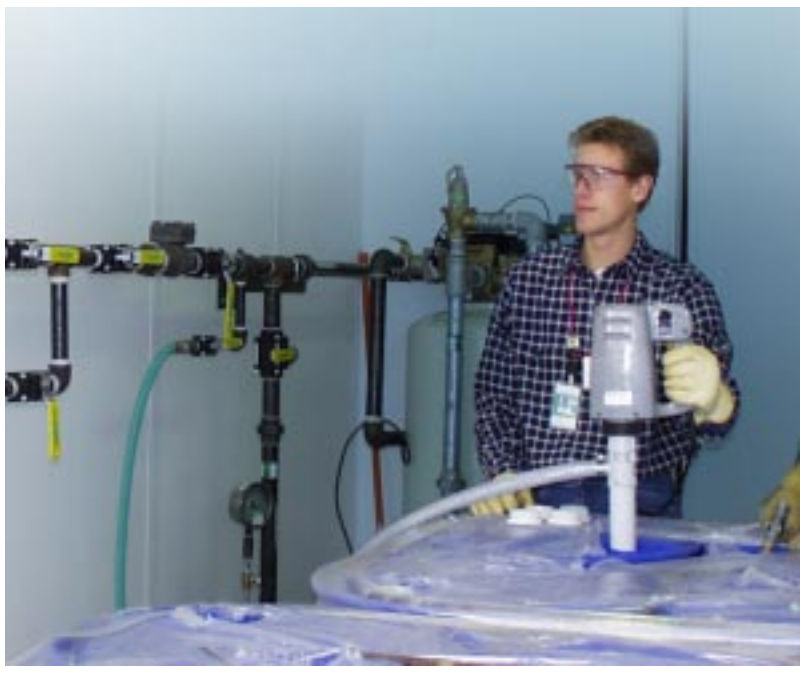
As part of INEEL's mission to advance subsurface cleanup science, the site launched a treatability study to test the viability of using enhanced in situ bioremediation at Test Area North. By 2000, the technique was working so well that the agencies decided to amend their original cleanup decision and incorporate in situ bioremediation into a better cleanup remedy.

Data show that the best, fastest, least-expensive way to clean up the groundwater is to:

- Use enhanced in situ bioremediation instead of pump-and-treat in groundwater around the old injection well, in what was the most contaminated part of the plume.
- Use pump-and-treat in the part of the plume with medium concentrations of contamination.
- Use a second innovation called monitored natural attenuation in the outer edges of the plume.

Monitored Natural Attenuation

With monitored natural attenuation, periodic groundwater samples are gathered at strategically placed monitoring wells to confirm computer models that INEEL scientists have developed. These models predict that TCE in the least-polluted part of the plume will break down to harmless by-products naturally before it would pose a threat to people or the environment – achieving cleanup in that part of the plume for less money than using pump-and-treat would cost.



Kent Sorensen uses sodium lactate to help natural bacteria break down subsurface chlorinated solvent contamination.

Overall, the new cleanup approach is estimated to cost about $7.75 million less over 30 years than using only pump-and-treat technology. That reduces the estimated cost of the cleanup over 30 years from $43.05 million to $35.27 million.

"This is what INEEL's Subsurface Science Initiative is intended to be – research and development – looking at processes that occur in the subsurface and controlling those processes in a way that beneficially affects contamination problems," Sorenson said.

(For more information, call Tim Jackson at 208-526-8484.)

Researchers use natural isotopes to learn how the aquifer flows

After three years of tromping through the desert and repeatedly sampling water from 66 different wells, a team of researchers is refining our understanding of groundwater movement in the Snake River Plain aquifer.

All water and rock contain trace amounts of naturally occurring radioactive and radiogenic elements such as thorium, uranium and strontium. These trace elements create an identifiable 'signature' as distinctive and traceable as a person's fingerprint.

Researchers examined water signatures from the aquifer and recharge sources (that replenish the aquifer) for clues about where water travels underground. As groundwater flows through rocks and soil, the ratios of these elements change—changing the signature of the water as well. Over time the signature of water becomes more similar to the signature of elements in surrounding rocks. Researchers tracked those changes as a method for locating aquifer flow zones.

This kind of research adds a finer level of detail to what scientists and regulators already know about the aquifer under the INEEL. Understanding the complex variables that affect fluid flow in the subsurface and contaminant movement is a critical area of research at the INEEL, and a primary mission for the U.S. Department of Energy.

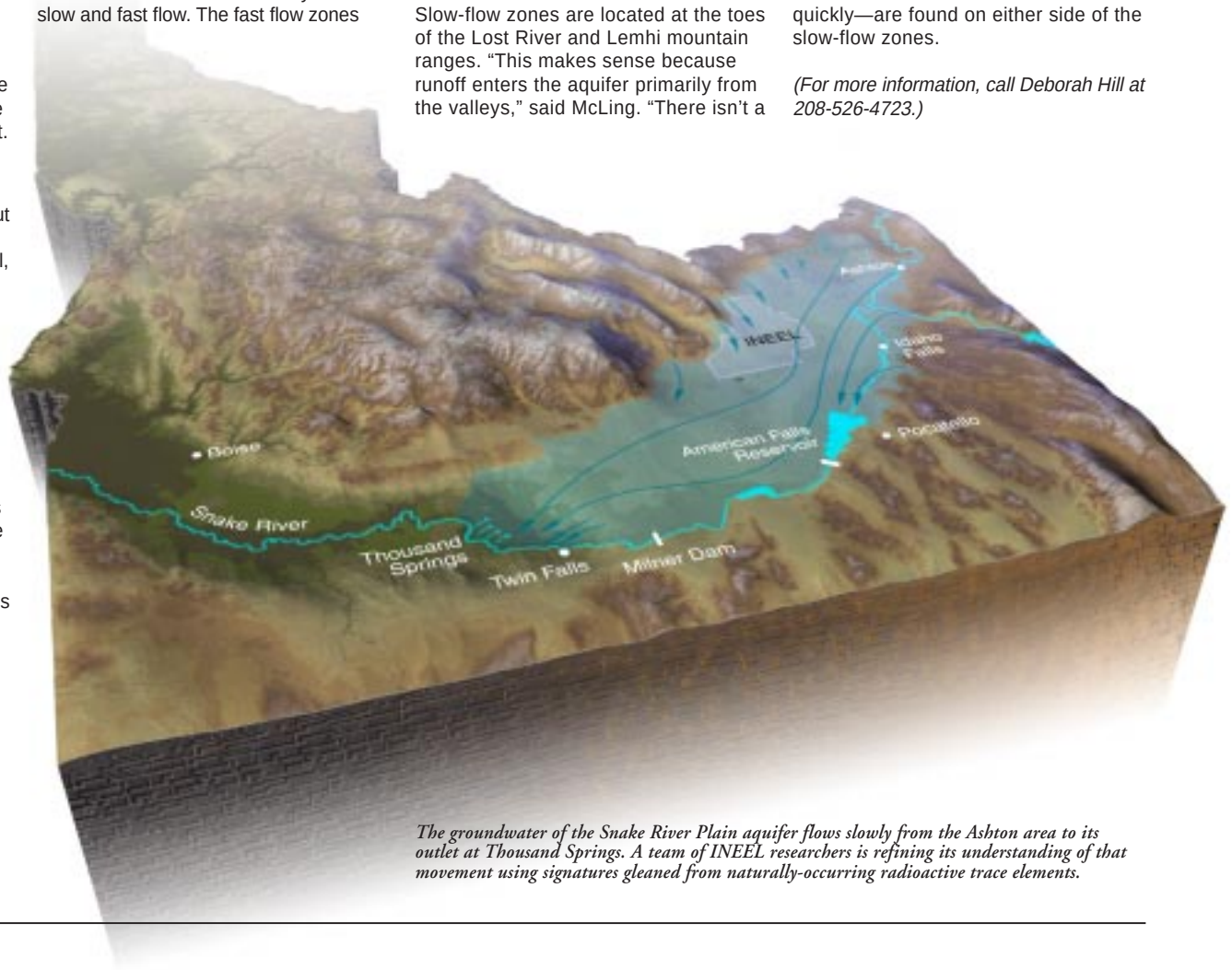
Water coming from the Little Lost River and Birch Creek replenishes the Snake River Plain aquifer. This recharge water has higher ratios of some elements than the rocks found in the aquifer itself. Researchers learned that water moving quickly through the aquifer retains more of the signature of the source recharge water because it doesn't have a lot of time to interact with surrounding rocks. Water that moves very slowly develops a signature that closely resembles the signature of the aquifer rocks.

Using the sample data to create a map, researchers were able to identify zones of slow and fast flow. The fast flow zones align with valleys north of the eastern Snake River Plain. "Water runs down the valleys and soaks into ground to enter the aquifer," explains INEEL geologist Travis McLing. "Think of the faster flow paths as underground extensions of water-saturated valleys."

Slow-flow zones are located at the toes of the Lost River and Lemhi mountain ranges. "This makes sense because runoff enters the aquifer primarily from the valleys," said McLing. "There isn't a lot of water coming off the toes of the mountain ranges."

These slow-flow areas act like boulders in the middle of a stream—water takes the path of least resistance and just flows around them. Faster-flow zones—areas where water flows more quickly—are found on either side of the slow-flow zones.

(For more information, call Deborah Hill at 208-526-4723.)



The groundwater of the Snake River Plain aquifer flows slowly from the Ashton area to its outlet at Thousand Springs. A team of INEEL researchers is refining its understanding of that movement using signatures gleaned from naturally-occurring radioactive trace elements.

SHIPP

Continued from page 1

system to vacuum out the vapors so they can be treated aboveground, a cheaper and more efficient method. These are real examples of how breakthrough science and engineering research can make our cleanup dollars stretch farther.

Another way to get the best science we can is through our partnership with the state's system of higher education. We recently entered into multi-million-dollar agreements with all three of Idaho's universities to help us develop a better understanding of Idaho's subsurface and how materials move through and interact with various soil types.

We need to know more. How do contaminants move? What gets absorbed, what passes through and why? Can we get better images of exactly how far a substance has migrated underground? These are also environmental questions facing many other Idaho communities, industries and whole segments of our economy. The answers we develop to these and related questions from the INEEL will help us continue to make far more informed waste management and cleanup decisions.

Over the next year, doctoral and post-doctoral researchers at Boise State University, the University of Idaho and Idaho State University will work together with their peers at the INEEL on many crucial projects. The knowledge developed will help guide ongoing and future cleanup at the laboratory. And what we learn at the INEEL will have applications for other Idaho industries, such as agriculture, mining and subsurface water protection efforts.

Additional science research is provided through our partnerships with other DOE laboratories and sites across the country. We're setting up effective teams to solve problems, and we're continuing to collaborate with other federal agencies, universities, private companies and foreign organizations.

Whether planning for specific INEEL cleanup or addressing broad multi-industry environmental issues, we, as taxpayers, must insist that solid and well-tested science serve as the foundation of our state and national cleanup and policy decisions. Science is a sound investment.

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A construction worker prepares a metal plate heated to 500 degrees F to melt the ends of two pipes so he can join them together (left).

PERCOLATION POND

Continued from page 1

from the ground surface to the aquifer, hundreds of feet below the surface.

The new research park, located two miles from the plant in an uncontaminated area, will give researchers access to real-time data on water infiltration through the vadose zone, the layer of unsaturated rock and sediment between the surface of the earth and the water table below. Liberally peppered with state-of-the-art hydrology and geophysics monitoring equipment, researchers will be able to take measurements at many different locations and depths. They will be able to remotely obtain data by telephone and plan to turn the information into three-dimensional pictures of the underground.

Long term, the new pond offers a valuable opportunity for scientific inquiry. Researchers will be able to monitor the new pond area before and after water is diverted to it—measuring how the vadose zone responds to the massive volume of water over time. Researchers will also be able to quantitatively measure how the variable flows of the Big Lost River affect the area.

"This is a tremendous opportunity to advance vadose zone research," said geohydrologist Dr. Larry Hull, science leader for the project. The research park will provide a "test bed" where conceptual models of fluid flow and contaminant transport can be evaluated, where new instruments can be installed side by side with existing technology for comparison, and where scientific investigations can be conducted to test hypotheses. The understanding of vadose zone processes gained at the percolation pond research park will be applied to environmental restoration, waste management, and facility operations problems across the INEEL.

(For more information, call Deborah Hill at 208-526-4723.)

The underground chemists

Microbes can't hide under the INEEL's desert site anymore — some INEEL investigators are enlisting their service. The microbes, with their penchant for chemistry, might be able to help clean up old contamination beneath the nuclear research facility.

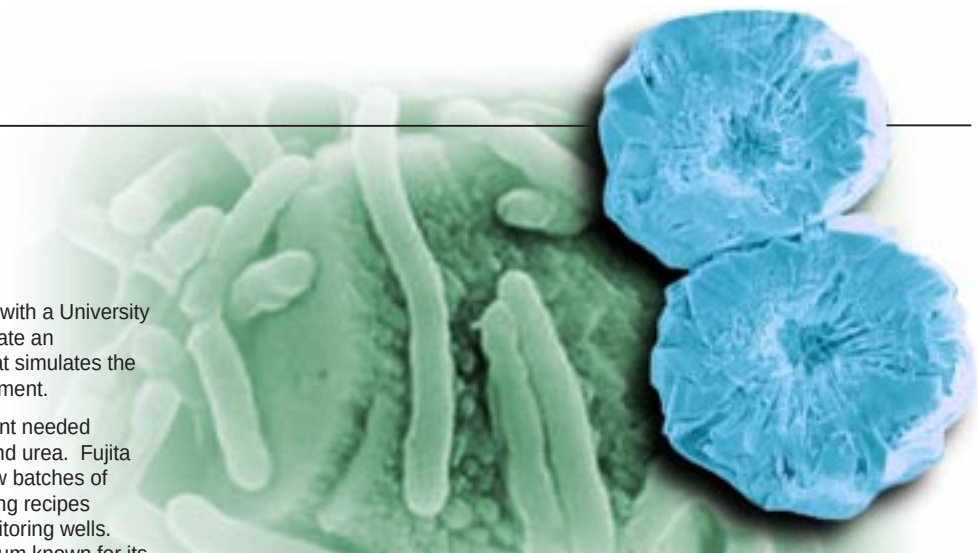
The researchers want to use the microbes to trap the contaminant strontium-90, a nuclear reaction breakdown product. The researchers think they can get strontium trapped in calcite crystals, a mineral that forms in low-acid environments, by coaxing the microbes to lower the acidity of their rocky environs.

"If we can trap strontium-90 in the subsurface, it's not going to keep moving with the groundwater," says INEEL microbiologist Yoshiko Fujita. "We want to stop it in place."

But they needed to test their ideas before applying them in the subsurface. To study the microbes aboveground, INEEL researchers collaborated with a University of Toronto scientist to create an aquarium-like mockup that simulates the microbes' natural environment.

The simulated environment needed groundwater, microbes and urea. Fujita started by mixing up a few batches of artificial groundwater, using recipes gleaned from INEEL monitoring wells. She then added a bacterium known for its ability to degrade urea. As the microbes did their job, their byproducts caused the acidity of the water to fall. Calcium carbonate fell out of solution and formed calcite, in the same way sugar falls out of solution to make rock candy.

But to determine if the crystals trapped strontium, INEEL analytical chemist Jani Ingram and chemical technician Byron White examined the crystal surfaces and broke down the crystals into their chemical components. The chemists found that the artificially grown calcite crystals did indeed contain strontium.



These photomicrographs show bacteria typically found beneath the INEEL's desert. INEEL researchers want to use the microbes to trap the contaminant strontium-90, a nuclear reaction breakdown product.

These preliminary studies set the stage for real underworld experiments, although Fujita expects more obstacles. "You never know what's going to happen moving from the lab to the field," says Fujita. "We don't know yet how many organisms will be out there or how much urea they'll break down."

They do know some microbes are out there though — last year, the researchers showed that INEEL groundwater harbored bacteria that could degrade urea. "For every sample of groundwater we tested, there was some hydrolysis of urea," Fujita said. "I think that's important because it shows this is a very common activity. If you rely on a reaction that is rare, your chances of going out in the field and having the method work are slim."

(For more information, call Mary Beckman at 208-526-0061.)

Treatment facility construction continues through the winter

Construction is advancing rapidly at the Advanced Mixed Waste Treatment Facility at the Idaho National Engineering and Environmental Laboratory. The facility will prepare plutonium-contaminated waste currently stored at the INEEL for shipment to the Waste Isolation Pilot Plant in New Mexico.

Completion of facility construction is projected for August 2002, four months ahead of schedule. The first shipments of transuranic mixed waste are expected to leave for the WIPP in March 2003.

Excavation of the site began on August 22, following receipt of its environmental permits and one day after a groundbreaking ceremony attended by state and local leaders, officials from the U.S. Department of Energy and representatives from BNFL Inc., the U.S. subsidiary of British Nuclear Fuels.

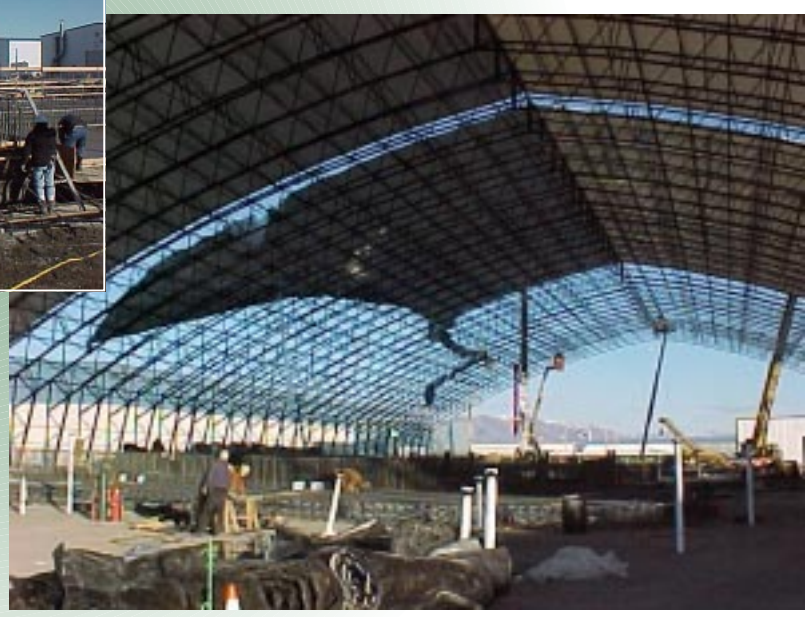
Since that time, the site has been excavated to bedrock and backfilled with packed soil to ensure a solid ground surface. Pouring of the concrete slab foundation began at the end of October.

Workers level the concrete slab for the Advanced Mixed Waste Treatment Facility (top). An enormous tent is being erected over the building site to allow pouring of the foundation and concrete slab through winter (right).

Now, an enormous tent is being erected over the building site to allow pouring of the foundation and concrete walls through the winter. The tent was in place by the end of December.

BNFL Inc. is a Fairfax, Virginia-based environmental cleanup company providing waste management, decontamination and decommissioning, and facility operations for the nation's most difficult environmental and nuclear challenges. The treatment facility project represents a $300 million private investment by the company under a 1996 DOE contract to finance, design, build and operate a facility to prepare 65,000 cubic meters of transuranic waste for shipment out of Idaho.

(For more information, call Ann Riedesel at 208-524-8484.)



INEEL continues to meet environmental milestone deadlines

Among the many deadlines the Idaho National Engineering and Environmental Laboratory has concerning waste treatment, movement and spent fuel handling, two loom on the horizon.

One involves sending waste to the Waste Isolation Pilot Plant in New Mexico. The other is moving core debris and spent nuclear fuel resulting from the 1979 Three Mile Island-2 accident in Pennsylvania from underwater storage at the INEEL's Test Area North to a new dry storage facility licensed by the Nuclear Regulatory Commission.

In both cases, progress is being made to meet the milestones.

The Idaho Settlement Agreement signed in 1995 by the state of Idaho, the U.S. Navy and the Department of Energy requires that 3,100 cubic meters (15,000 drums) of transuranic waste must be shipped to WIPP by Dec. 31, 2002. Transuranic waste is material such as gloves, tools, clothing and laboratory instruments contaminated primarily with trace amounts of plutonium and americium.

As of Jan. 4, 2001, the INEEL had shipped about 210 cubic meters of transuranic waste to WIPP. The laboratory plans to ship 1,160 cubic meters between Oct. 1, 2000 and Sept. 30, 2001. In fiscal year 2002, 1,483 cubic meters will be shipped from the INEEL. Finally, between October 2002 and December 2002, the remaining 418 cubic meters will be shipped.

Transportation requirements limit the amount of hydrogen gas allowed in each highway TRUPACT II shipping container. Hydrogen gas is a by-product of the breaking down of organic materials present in the waste. To help meet the deadlines, the INEEL developed an innovative gas generation test sampling system that allows direct measurement of hydrogen gas inside the drums. The new system significantly speeds up qualification of waste drums for shipping to help meet the milestone.

Movement of the TMI-2 material is just as important a project, although the distance covered by the moves is not nearly as long as the WIPP shipments.

The INEEL is storing underwater at Test Area North the core debris and spent nuclear fuel from the TMI-2 accident. The Idaho Settlement Agreement stipulates that by June 1, 2001, all the TMI-2 material must be moved into the new dry storage facility at INTEC about 25 miles south of TAN. Transfer of the material will require 29 shipments.

As of Jan. 4, 2001, the INEEL had shipped about 210 cubic meters of transuranic waste to WIPP. The laboratory plans to ship 1,160 cubic meters between Oct. 1, 2000 and Sept. 30, 2001.

The project included construction of the NRC-licensed Independent Spent Fuel Storage Installation—the first such dry storage facility at the INEEL—and a system for removing from underwater storage and completely drying the containers holding the spent nuclear fuel and core debris. The project also involves using a specialized shipping cask and transport vehicle for moving the spent nuclear fuel and debris containers and placing them into the dry storage modules.

Although the June 2001 deadline is an aggressive schedule, INEEL officials are committed to meeting it.

(For more information, call John Walsh at 208-526-8646.)

Pumping up rechargeables

Rechargeable lithium batteries haven't *really* lived up to their expectations. They run down when they're not being used, get old and stop taking charges, and freeze if they get too cold.

INEEL chemists have given lithium rechargeables a new heart — a solid center with unique properties that lets the batteries operate even in really cold temperatures. The new batteries also have a much longer shelf-life and are safer than conventional batteries.

At the heart of the matter

The solid center of the new battery is a mix of a gel-like polymer and a powdery ceramic that turns into a clear membrane when properly blended together. The membrane serves as a battery electrolyte — the substance that regulates a battery's electrons to generate an electrical charge. "It's a magic plastic that performs surprisingly well," says Mason K. Harrup, an INEEL chemist with big plans for the batteries. "We want to get them into space, maybe even to Mars."

A hard heart stays true

Originally developed by Eastman-Kodak for anti-static purposes, Harrup and colleagues found that when sandwiched between two electrodes, the membrane would act as an electrolyte. The membrane conducts positive lithium ions but not electrical current, ideal properties for a battery electrolyte. The membrane would replace the liquid and gel electrolytes in conventional rechargeable lithium batteries. The solid membrane doesn't leak in the battery, and unlike liquid and gel electrolytes, they don't form insulating deposits and eventually cause battery death.

The solid electrolyte prevents unused batteries from running down, too. Liquid and gel electrolytes provide an imperfect electrical barrier and the electrons trickle between the electrodes — the longer a battery sits, the more charge it loses. Harrup has shelved prototype INEEL batteries for a year without having to recharge them. One-time-use lithium watch batteries have an insulating barrier that slows the charge leak, but also prevents the battery from being recharged.

Safe space

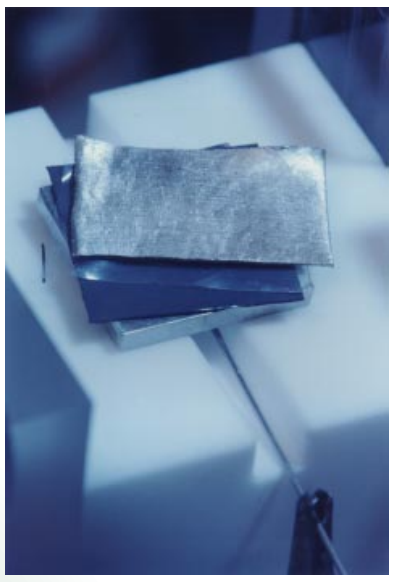
The solid electrolyte — essentially a plastic — is also a lot safer than conventional electrolytes. The liquid electrolytes in currently available lithium batteries are usually flammable, and the reason they can explode upon recharging.

Most exciting is the potential for batteries made with the INEEL electrolyte to travel the cold reaches of space. The membrane doesn't melt at high temperatures that degrade conventional electrolytes and continues to function at about 100 degrees Farhenheit below zero, unlike liquid and gel electrolytes that freeze. Satellite companies and NASA have expressed an interest in their development.

INEEL's lithium battery recently topped a list of over 100 technologies that demonstrates the DOE commitment to save money and improve the quality of life for consumers. The battery received the Energy@23 and Bright Light awards.

(For more information, call Mary Beckman at 208-526-0061.)

The heart of the INEEL's new lithium battery is a mix of a gel-like polymer and a powdery ceramic that turns into a clear membrane when properly blended together (far left). When sandwiched between two electrodes, this membrane acts as an electrolyte, replacing the liquid and gel electrolytes found in conventional rechargeable batteries (below).



An INEEL scientist directs a pressurized stream of molten metal onto a copper wheel spinning at 100 miles per hour (left). The metal cools almost instantly into a shiny metallic glass ribbon, as fine and flexible as Christmas tree tinsel (above).

Researchers create mighty magnets

Researchers at the INEEL have discovered a way to make magnets used in computer hard drives and motors more powerful and durable and also slash manufacturing costs.

Materials scientist Dan Branagan found that two important steps created significantly stronger magnets.

Branagan and his colleagues added additional elements to the formula for these high-end magnets, known as rare earth magnets from their mix of rare earth elements, then formed a metallic glass. These steps resulted in metal with a unique structure, a sort of raw material for magnets.

Magnets are actually a composite of thousands of miniature magnetic fields called domains. Usually, these domains point in many different directions. If researchers can get the domains all pointing the same way, then the magnetic field will be extremely strong.

At the INEEL, Branagan forms magnets composed of grains so tiny that each one is too small to host more than one direction of magnetic field. This ability to control grain size and improve magnetic strength translates into smaller, but more powerful, magnets. The key is the unique structure of the raw material – microscopic amorphous blobs less than one hundredth of a millionth of a meter across, about 500 times smaller than a red blood cell.

Researchers can use two different methods to control the grain size; both involve making metallic glass. To coax the mix of elements into microscopic form, a pressurized stream shoots molten metal onto a copper wheel spinning at 100 miles per hour. The metal cools almost instantly into a shiny metallic glass ribbon, as fine and flexible as Christmas tree tinsel.

They can also form a powder of metallic glass by injecting the molten metal into a pressurized stream of gas. Similar to a volcanic eruption, the gas stream instantly cools the melt into thousands of tiny glass particles.

Heating the metallic glass in an oven morphs the glass blobs into crystals. Normally, heating causes the blobs to grow together into large crystals, creating large grains with multiple domains. But the additional elements added to the original mix create non-metallic crystals that plug the spaces between the larger metallic ones, preventing them from growing too big.

This raw magnet material can be formed into a variety of shapes and sizes, reducing machining and finishing costs in magnet production. Manufacturers will be able to use this method to improve household electronics and motors, for example, by miniaturizing computer hard drives.

(For more information, call Mary Beckman at 208-526-0061.)

Generation IV

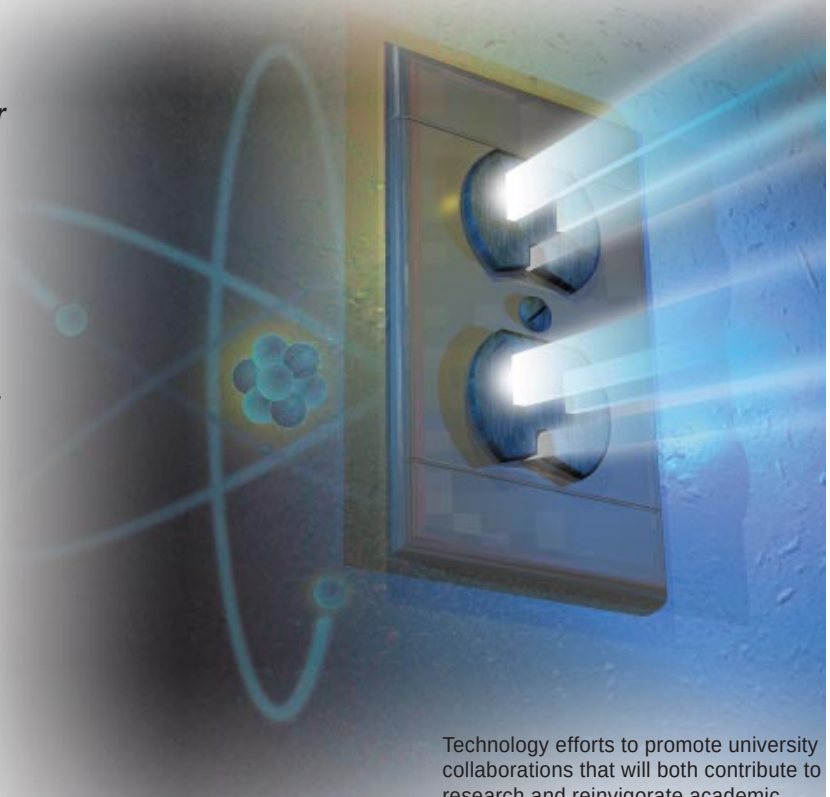
Improved nuclear power for an energy-hungry world

The Idaho National Engineering and Environmental Laboratory wants to build on its roots—supporting research and development and testing nuclear power reactors. The INEEL plans to do just that through its lead role in the Generation IV (Gen IV) Nuclear Energy Systems Initiative.

The INEEL and Argonne National Laboratory, U.S Department of Energy lead labs in nuclear reactor technology, are leading DOE's initiative to develop the next generation of nuclear power reactors. The goal of the Generation IV initiative is to design one or more nuclear energy systems that can be licensed, constructed, and operated in a manner that will provide a competitively priced supply of electricity while satisfactorily addressing issues of nuclear safety, waste, proliferation, and public perception concerns in the countries where it is deployed.

In the short term, the INEEL and ANL are leading a two-year technology "roadmap" effort to:

- Define technology-independent goals for the nuclear energy systems.
- Identify paths forward to enable certification and deployment of those systems.
- Define R&D activities to support design and certification.



The roadmap effort will involve six technical working groups, each studying a particular reactor technology. The groups include scientists and engineers from industry, national laboratories, universities and international experts.

John Ryskamp, INEEL Gen IV Initiative leader, said the INEEL is also funding research of several reactors and reactor fuel ideas with laboratory-directed research and development money. The laboratory is actively supporting DOE's Office of Nuclear Energy, Science and Technology efforts to promote university collaborations that will both contribute to research and reinvigorate academic curriculums in nuclear energy. Additionally, the INEEL wants to create research collaborations with industry that involve INEEL researchers and could bring some of that research and development work to Idaho.

Finally, the INEEL and ANL hope to promote new business for existing facilities to test nuclear fuels, materials and reactor designs.

DOE's Office of Nuclear Energy, Science and Technology leads an effort to attract broad international support and cooperation by establishing a Generation IV International Forum. The forum, to date, involves nine countries including the U.S. Other members are the United Kingdom, France, Japan, Canada, Argentina, Republic of Korea, Republic of South Africa, and Brazil.

DOE officials believe nuclear energy is an essential part of the future energy mix to meet future energy supply needs worldwide. This will require using the best existing energy-generating technologies as well as future innovative technologies, including advanced nuclear power systems.

Generation IV nuclear power systems would follow three other distinct periods of reactor development:

The first generation (Gen I)
— in the 1950s and 1960s was experimental reactors.

The second generation (Gen II)
— in the 1970s and 1980s was the large, central station nuclear power reactors, and 104 of these plants still operate in the U.S. and provide about 20 percent of this country's power.

The third generation (Gen III)
– in the 1990s was the advanced light-water reactors built primarily in eastern Asia to meet that region's expanding electricity needs.

John Kotek, ANL Gen IV Roadmap project manager, says the ultimate goal of the Gen IV Initiative is to have one or more reactor designs certified by 2030 when the majority of generation II plants would turn 60 years old.

(For more information, call John Walsh at 208-526-8646.)

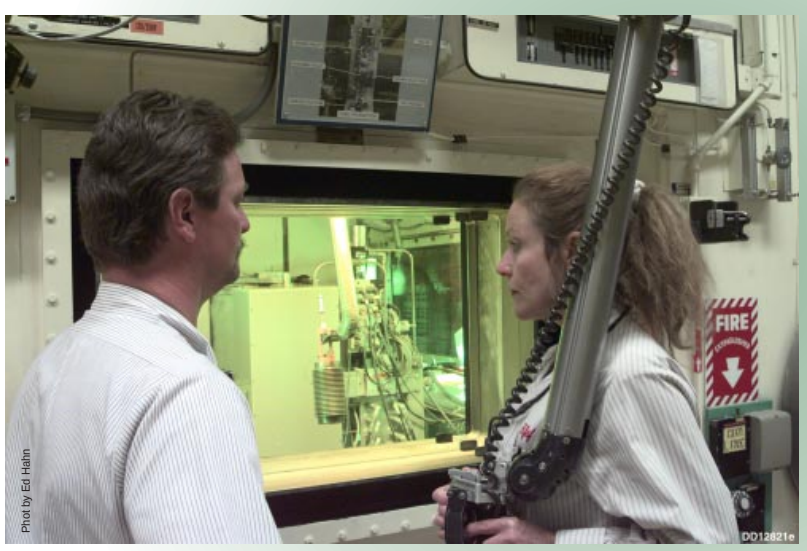
Argonne-West turns the corner

After six years of challenge and uncertainty, Argonne National Laboratory – West is poised for several years of programmatic stability and growth at the Idaho National Engineering and Environmental Laboratory.

For more than 50 years, Argonne – West has been a national center for nuclear technology development and testing. In fact, every operating nuclear power station in the world today -- making 17% of the world's electricity and 20% of American electricity -- traces its design and development through Argonne-West.

In 1994, however, the United States terminated its last remaining advanced reactor research program, the Integral Fast Reactor program being conducted at Argonne–West. This program used a nuclear fuel designed for efficient recycle in order to wrest all the energy value from the fuel. Current generation reactors only use 1% to 2% of the energy value in the fuel. Argonne's new fuel, while offering many technical and operational advantages, is not sufficiently stable for permanent disposal.

This was widely recognized, and Argonne was authorized to complete development and demonstration of a new fuel treatment technology, called Electrometallurgical Treatment, to assure environmentally safe disposal of the fuel. This demonstration is now complete. Following extensive environmental impact analysis and a rigorous technical oversight by the National Academy of Sciences, the Department of Energy has authorized Argonne to apply this technology to its remaining inventory of nuclear fuel.



Argonne National Laboratory-West technicians Darrell Wheeler and Christal Mason perform remote handling operations at Argonne's Hot Fuel Examination Facility.

Treating this fuel to prepare it for permanent storage will take from seven to 12 years and will provide a basis of programmatic stability for Argonne-West during those years. This work is not only the necessary and right thing to do to properly manage this material for the long-term, it also is a necessary step to assure that the terms of the Idaho Settlement Agreement with the DOE to remove spent nuclear fuel from Idaho by 2035 are met.

Argonne National Laboratory – West is operated by the University of Chicago for the U.S. Department of Energy.

(For more information, call Paul Pugmire at 208-533-7331.)

Palm-sized radiation detector will thwart smuggling

Smuggling nuclear material across the border just got tougher, thanks to an award-winning, palm-sized device developed at the Idaho National Engineering and Environmental Laboratory.

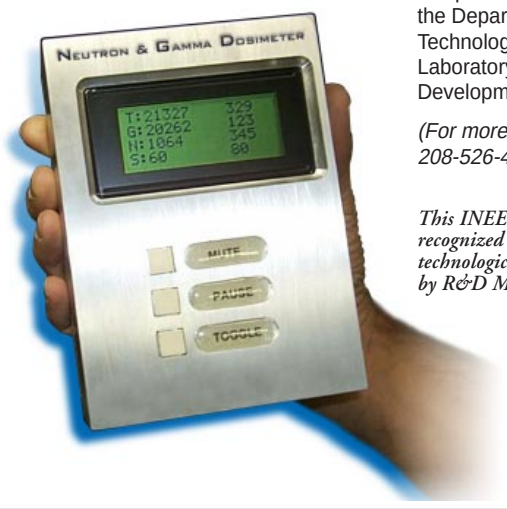
Nuclear scientist Rahmat Aryaeinejad's dosimeter simultaneously detects two types of radiation—gamma rays and tiny particles called neutrons—and has been recognized as one of the 100 most significant technological achievements for the year 2000 by *R&D Magazine*.

Aryaeinejad began work on his sandwich-sized, aluminum-cased detector in 1997 to solve a problem for U.S. Customs. In the day-to-day duties of national defense, commonly transported radioactive medical isotopes were a constant source of false security alarms for Customs officials. Customs needed to quickly detect the kinds of radioactive materials they really worry about—materials such as weapons-grade plutonium.

The lithium-based dosimeter signals the presence of radiation in three ways—visually on a tiny display screen, audibly through an alarm, or tangibly through vibrations. The dosimeter eliminates the need to carry two bulky instruments in the field—one for gamma rays and another for neutrons. There are no films to develop and staff does not need to be highly trained. The dosimeter—powered with four standard AA batteries—has a data port for downloading information into a computer.

The dosimeter has broad applicability in any environment where real-time radiation monitoring is important, such as personnel working at nuclear power plants, patients undergoing radiation therapy, or managing spent nuclear fuel and remediation sites containing radioactive material.

In the future, Aryaeinejad plans to miniaturize the dosimeter even more—making it the size of a pack of cigarettes. He also plans to create an instrument for locating and identifying radioactive contamination in the subsurface and measuring the rate of contaminant migration.



The sensor research was funded by the Department of Energy Office of Nonproliferation and National Security, the Department of Energy Special Technologies Program, and the INEEL Laboratory Directed Research and Development Program.

(For more information, call Deborah Hill at 208-526-4723.)

This INEEL-developed dosimeter has been recognized as one of the 100 most significant technological achievements for the year 2000 by R&D Magazine in Chicago.

Site helps wage war against chemical weapons

What you don't know might certainly kill you when it comes to chemical warfare. Working to solve this problem, INEEL researchers have developed equipment to detect minute amounts of dangerous chemicals on rock, concrete, and many other surfaces.

The heart of this specialized detector is a secondary ion mass spectrometer, or SIMS for short. A SIMS looks like an alien diving bell, with shiny metal projections, bolts, and plexi-glass viewing ports surrounding a central sphere.

INEEL chemist Gary Groenewold and his colleagues use the SIMS to detect and identify chemicals by mass. In one experiment, they discovered that the dangerous chemical weapon VX, a "human pesticide," quickly degrades on concrete – now military personnel know how long to wait before securing a VX-tainted concrete runway.

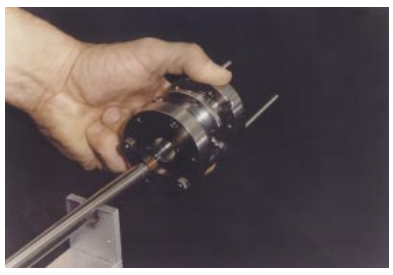
A SIMS works by sending a beam of charged particles, known as primary ions, toward a sample. Researchers only need a tiny sample — enough to fit on a small nail head (the nail holds the sample deep within the SIMS). When the particles hit the sample, they knock charged particles called secondary ions off the sample. The secondary ions stay trapped within the SIMS. Hitting the ions with a radio wave pulse causes the ions to oscillate.

"The ions are like marbles on a trampoline," explains Groenewold. "Increasing the radio wave frequency increases the oscillation, bouncing the ions off into the detector." The ions tumble into the detector at a rate relative to their mass. But many different molecules can have the same mass, so the scientists devised tricks to identify different chemicals. One trick involves breaking a molecule into its atomic components in the SIMS; different molecules have different, characteristic, components.

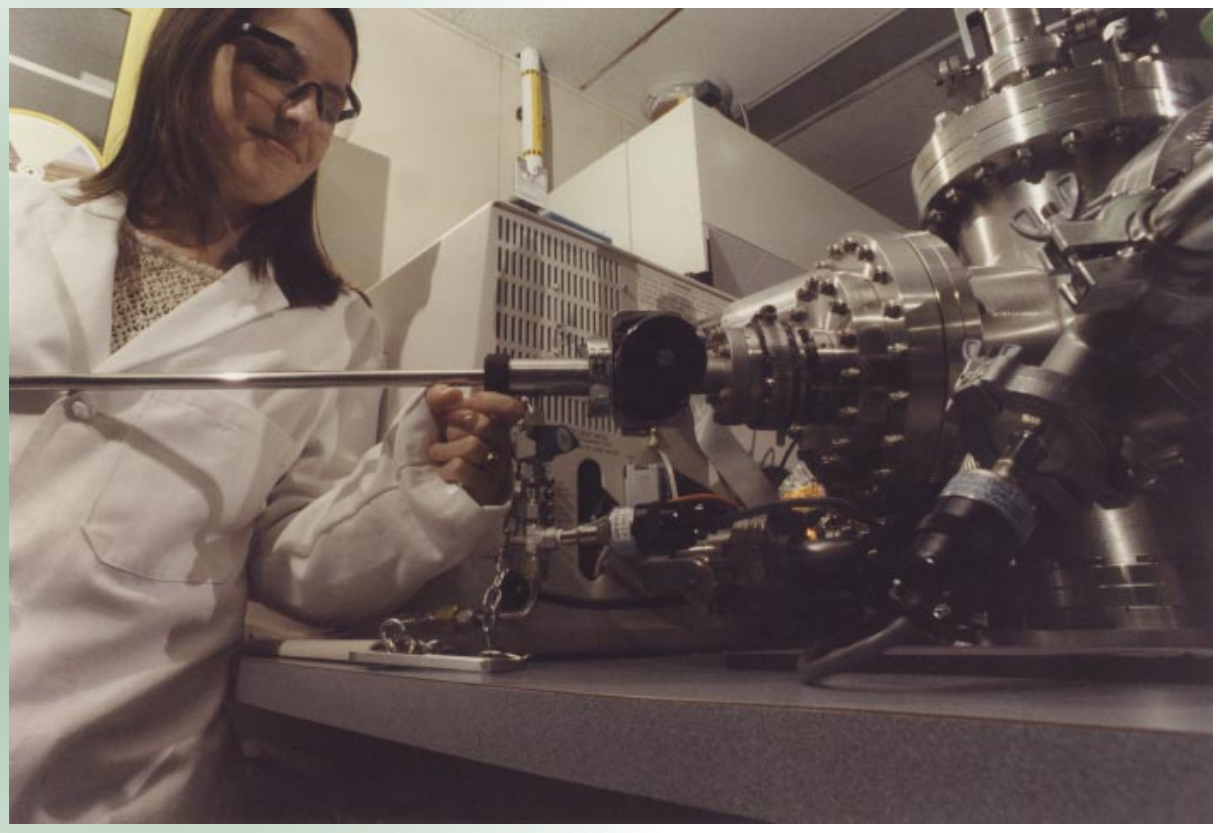
The SIMS has a strong advantage over the method typically used for chemical weapons monitoring. Currently, United Nations weapons inspectors use gas chromatography, which requires dissolving samples, then extracting samples as gas and analyzing the gas in a laboratory instrument – a process that takes hours.

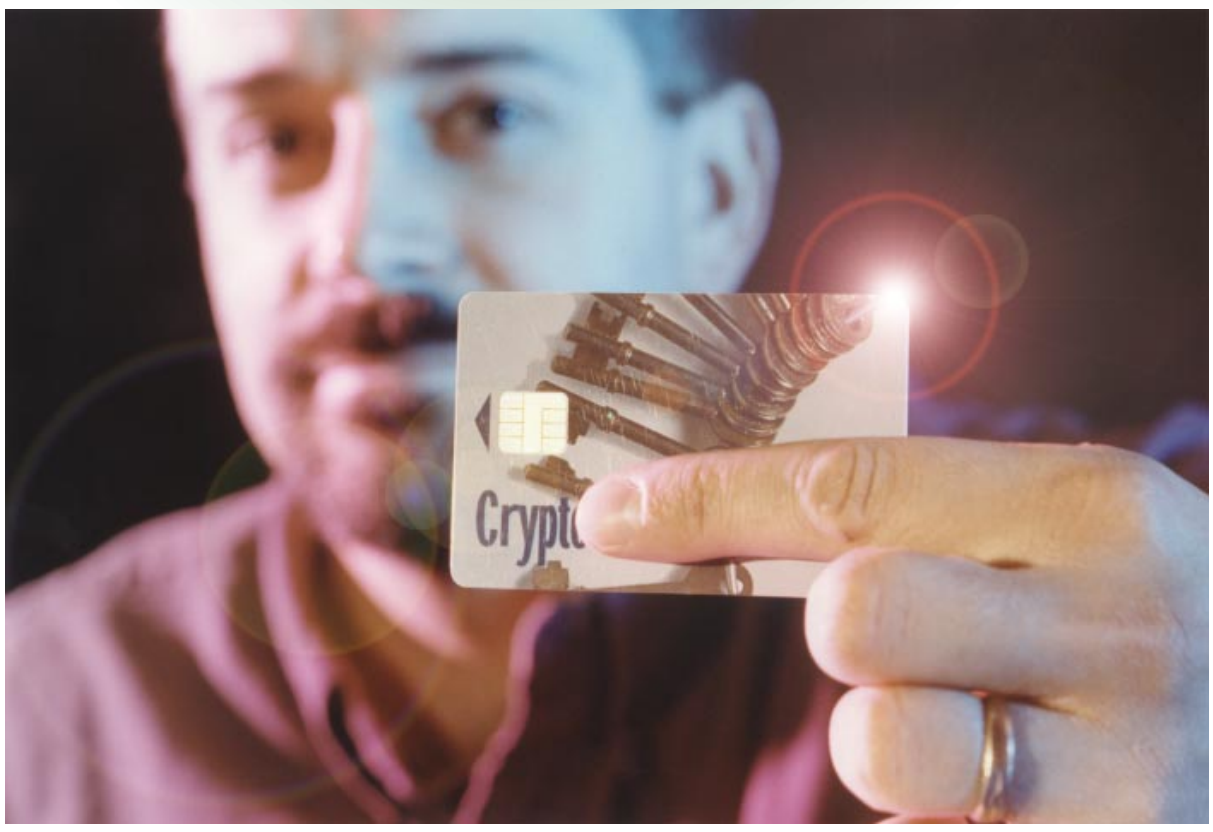
But SIMS samples require no special preparation, other than buying nails at the local hardware store. "Things that usually take hours or days with chromatography take us five minutes," says INEEL chemist Gary Gresham. That means weapons inspectors could analyze many more samples in their allotted time, and possibly find otherwise overlooked evidence of chemical weapons manufacturing. The INEEL team currently is developing portable SIMS machines for use in just these kinds of situations.

(For more information, call Mary Beckman at 208-526-0061.)



Analysts mount samples on this direct insertion probe using double-sided tape (above) and insert the probe into the SIMS (below). An ion trap SIMS instrument measures minute amounts of chemicals.





The Idaho National Engineering and Environmental Laboratory is using smart cards in a revolutionary digital signature process developed for databases.

Signing on the dotcom line

Digital signatures and databases sign away paperwork

Smart cards look and feel like simple credit cards. But they act like tiny computers. The Department of Energy's Idaho National Engineering and Environmental Laboratory is using smart cards in a revolutionary digital signature process developed for databases.

A digital or electronic signature gives personal approval through computers and networks rather than signing a piece of paper. Electronic signatures, from simple image scans to encrypted programs, are being developed the world over. Last October, the U.S. passed a law that made digital signatures legally acceptable.

The INEEL digital signature process, developed for managing and shipping nuclear waste, represents one of the most complex uses of digital signatures yet. The combination of government regulations, transportation requirements and environmental concerns makes shipping waste a monumental paper producer, as many as 1,000 pages per drum of waste. The INEEL electronic waste management process and its digital signature make shipping waste all but paperless.

The patent-pending INEEL process allows a person to "sign" information that resides in hundreds of different locations on computer databases, unlike other digital signatures that sign only one file. The compiled information is sent to a microprocessor chip on the smart card where it is tightly compressed and encrypted to create the signature. The information and the signature are inseparable.

Similar to those commonly found on other smart cards, the INEEL electronic signature is made up of private and public keys. Mathematical encryption formulas create public and private keys simultaneously — the private key signs electronic documents and the public key proves the signature's authenticity. The private key stays in the smart card with the signer, and the public key is available wherever the signature needs to be verified.

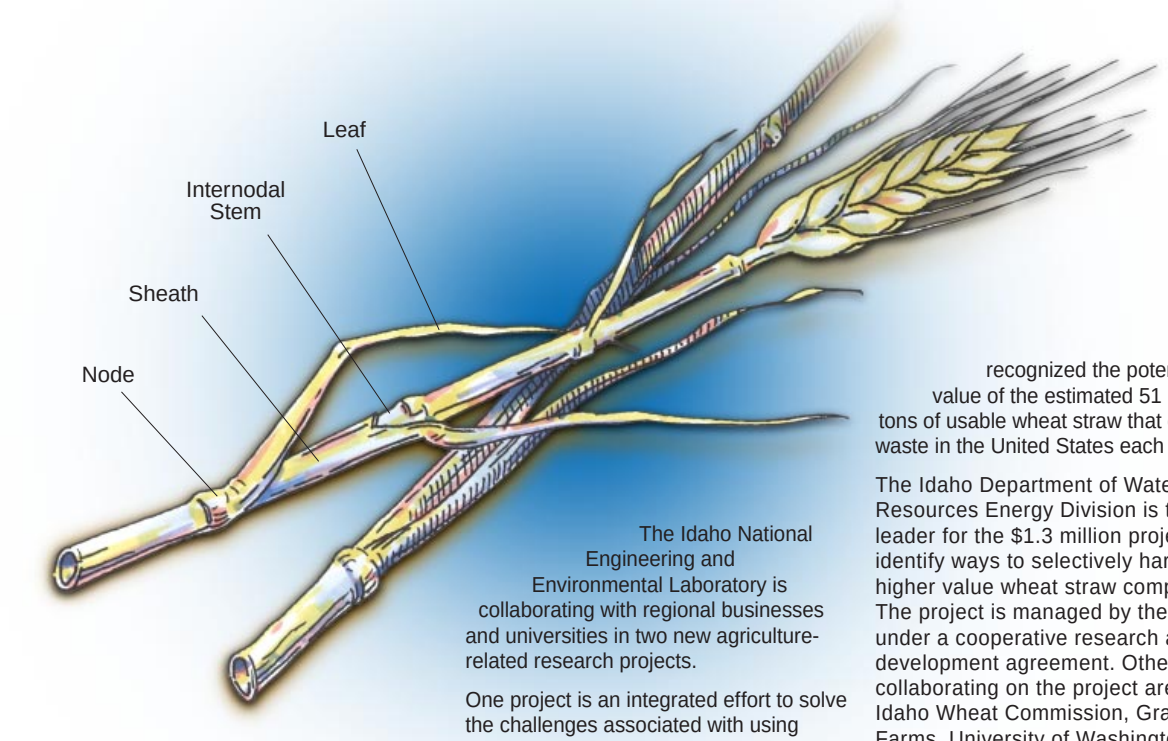
After INEEL employees insert their smart card and PIN into the electronic waste management system, they can approve forms as with any electronic system. However, the information they are approving is assembled from thousands of data points within the management system, such as from databases of transportation and federal government requirements. During signing, the information is compressed and encrypted entirely on their card's microprocessor.

For INEEL employees managing and shipping nuclear waste, the electronic waste management system also keeps track of any changes to the information the employee originally approved. Changes are flagged by the system for the employee to clarify, much like contract changes require the signer's initials.

The INEEL's waste management process represents one of the most complex digital signature applications and one of the few production uses of smart cards within the Department of Energy.

(For more information, call Kathy Gatens at 208-526-1058.)

Teams collaborate in bioagriculture research



One of the new projects on which the INEEL is collaborating is an integrated effort to solve the challenges associated with using straw residue for bioenergy and bioproducts.

The Idaho National Engineering and Environmental Laboratory is collaborating with regional businesses and universities in two new agriculture-related research projects.

One project is an integrated effort to solve the challenges associated with using straw residue for bioenergy and bioproducts. The three-year research effort is focusing on a process for upgrading wheat straw to more desirable feedstock products. Industry has recognized the potential value of the estimated 51 million tons of usable wheat straw that go to waste in the United States each fall.

The Idaho Department of Water Resources Energy Division is the team leader for the $1.3 million project to identify ways to selectively harvest the higher value wheat straw component. The project is managed by the INEEL under a cooperative research and development agreement. Others collaborating on the project are the Idaho Wheat Commission, Grant 4-D Farms, University of Washington, Washington State University, University of Idaho and Energy Products of Idaho.

Amalgamated Research, Inc. (ARi) in Twin Falls will receive $1.9 million over the next three years from the U.S. Department of Energy as part of a federal effort under the Office of Industrial Technologies Industries of the Future program to stimulate the nation's biobased products industry. This research project is in partnership with the INEEL and a consortium of national and international sugar production, membrane production and biomass refining companies. The total three-year project is $4 million, with the DOE providing $1.9 million, and ARi and the consortium providing $2.1 million.

"This project is an excellent example of how the Industries of the Future program is helping Idaho's agricultural, forestry and mining industries compete using cutting-edge technology," said Robert Hoppie, administrator of the Idaho Energy Division.

The funds will support a new biomass refining system for purifying and separating biomass subcomponents (sugars or other chemical building blocks). Currently, biomass refineries are marginally effective due to their high cost. Partnership researchers will use these funds to improve biomass refinery efficiency by 25 percent, while reducing capital equipment costs of biomass purification and separation systems 10-fold.

(For more information, call Teri Ehresman at 208-526-7785.)

Seven universities work with INEEL on collaborative research projects

Thirteen research projects have been selected for initial funding as part of the first joint collaborative effort between the Inland Northwest Research Alliance and the Department of Energy's Idaho National Engineering and Environmental Laboratory.

This research is oriented toward gaining a better understanding of subsurface conditions and various contaminants present at the INEEL site, as well as other DOE facilities. The goal is to develop environmental cleanup methods that can be used in a variety of applications.

INRA funding for the projects will total about $3 million over three years and fund Ph.D. and postdoctoral researchers who will work on collaborative projects. The various INRA member institutions will contribute another $1 million toward the success of the projects. These young researchers will spend time on their projects at the INEEL and at the various INRA institutions. The collaborative projects are designed to stimulate additional collaborations between the faculty at the INRA member institutions and the researchers at the INEEL, and to prepare a new work force for the INEEL.

"We hope to use these projects to help build the science base for the laboratory, as well as new funding opportunities for our institutions," says James Petersen, interim executive director of INRA.

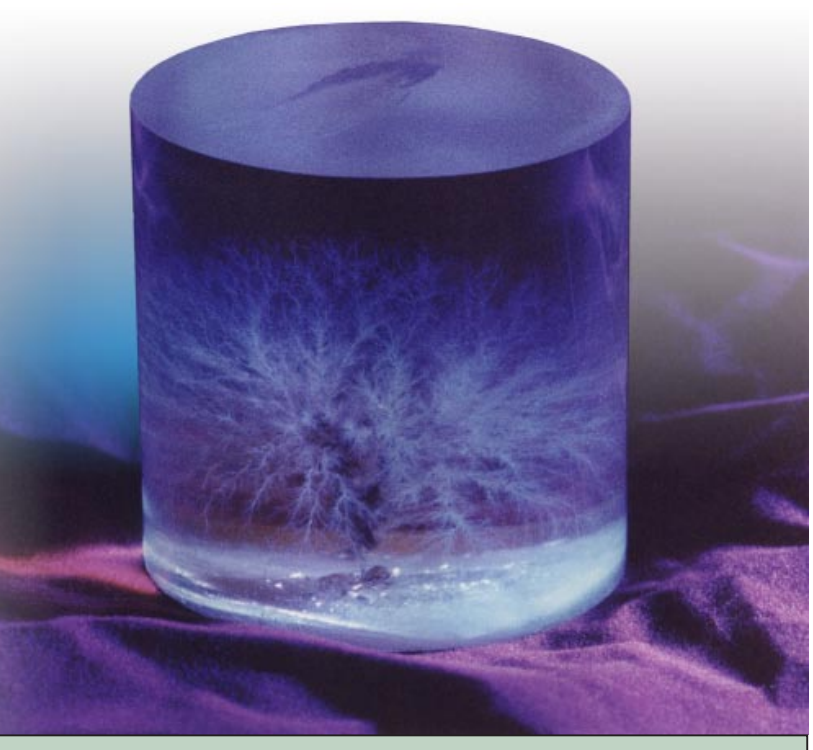
Seven universities formed the Inland Northwest Research Alliance in the spring of 1999. The member universities include Boise State, Idaho State, University of Idaho, Montana State, University of Montana, Utah State and Washington State. INRA is a partner with Bechtel BWXT Idaho, the corporation responsible for managing and operating INEEL. In its managing role, INRA will help set the direction for scientific research performed at INEEL.

"One of the objectives of INRA is to fund excellence," says Petersen. "This collaborative effort is a way to focus on the good science going on at the INEEL and the universities. These projects demonstrate how INRA is a benefit for the universities, INEEL and the region."

The 13 projects were selected from 26 proposals received.

(For more information, call Teri Ehresman at 208-526-7785.)

The INEEL and ISU are collaborating on research at the Idaho Accelerator Center in Pocatello. When a powerful electric current is passed through a lucite cylinder, the organic-looking burn pattern branches into a tree-like structure of incredible intricacy. This spark tree was created using a high energy electron beam from a linear accelerator.



Economic development efforts bring 830 new jobs to Idaho

If Bechtel BWXT Idaho (BBWI's) first year is any indication, its five-year promise to create 3,000 new jobs independent of the laboratory is certainly a goal within reach.

After the first 12 months of BBWI's five-year contract to manage and operate the Idaho National Engineering and Environmental Laboratory, 830 new jobs have been created in Idaho as a result of economic development efforts across the state.

With a corporate-funded annual budget of $1.4 million not associated with the Department of Energy, Chris Hertz, BBWI Economic Development director, says the money is first spent on job creation to support the local economic development organizations. Second, the INEEL supports businesses directly by helping create, expand and retain jobs. "We're here to fill in the gap when the local organizations have done all they can do," said Hertz.

While the money is essential, still crucial to success are BBWI's efforts to work closely with the Idaho Department of Commerce and other economic development organizations around the state to help create the new jobs. "We meet with them, evaluate the situation and develop strategies. Not until all other resources have been exhausted are we able to assist them financially," said Hertz.

The largest number of new jobs created was with Tele-Servicing Innovations (TSI), a customer contact center headquartered in Idaho Falls. TSI received two grants totaling $247,500 allowing expansion of its Idaho Falls office and opening additional offices in Burley and Salmon. The result was the creation of 146 new jobs with an average wage of $11 to $12 an hour. An additional TSI customer contact center was recently opened in the Silver Valley of northern Idaho.

The 830 new jobs represent 28 percent of BBWI's goal of 3,000 jobs by Oct. 1, 2004, a goal Hertz feels the company can achieve. "I'm very confident we can create the 3,000 jobs over the next five years," said Hertz. "Idaho has a very sound infrastructure for economic development and there is a great sense of caring by the people for their communities."

(For more information, call Steve Zollinger at 208-526-9590.)